IN THE CLAIMS

The following is a listing of the claims in the application with claims 15, 16, 17, 18, 21, 22, 23, 24, 25, 28 and 29 shown as amended.

LISTING OF CLAIMS

1. (original)   System for automatic determination of the density of an object (100) belonging to a set of objects, characterized in that it comprises:

- an apparatus (2) to determine a significant dimension (x) of said object (100),

- an apparatus (30) to determine the intensity (I) of a photon beam attenuated by passing through said object (100),

- an acquisition, processing and analysis apparatus (200),

- means (70, 72, 80, 82, 84, 86, 88) of transporting the object (100) to the apparatus (2) for determining its significant dimension (x) and towards the apparatus (30) for determining the attenuated photon intensity,

- first means (74, 76, 78) of adjusting the position of the object (100) relative to the apparatus for determining its significant dimension (x), and

- second means (90, 92, 94, 96, 98) of adjusting the position of the object (100) relative to the apparatus (30) for determining the attenuated photon intensity,

and in that said first and second adjustment means are capable of moving the object (100) with a precision of the order of one micron with respect to a support plate (150) on which the elements making up the system are installed,

and in that the position of the object (100) relative to the apparatus (30) for determining the attenuated intensity (I) is adjusted as a function of the significant dimension (x) of said object (100).

2. (original)   System set forth in claim 1, characterised in that the acquisition, processing and analysis apparatus (200) includes a computer (170) in which a dedicated software is installed that runs series of instructions and calculation algorithms used in the automatic method for determination of the density of the object (100).

3. (previously amended) System set forth in claim 1, characterised in that the acquisition, processing and analysis apparatus (200) gives the relative variation ($\frac{\Delta\rho}{\rho}$) of the density (ρ) of the object (100), relative to the known density of at least one standard density object (emas) belonging to the same set of objects (100).

4. (previously amended) System set forth in claim 1, characterised in that the apparatus (2) for determination of the significant dimension of the object (100) includes:

- a first infrared assembly (4, 6) composed of a first infrared emitter (4) and a first infrared receiver (6),

a second infrared assembly (8, 10) composed of a second infrared emitter (8) and a second infrared receiver (10),

the two infrared assemblies (4, 6; 8, 10) being separated from each other by a known distance (d), and emitting infrared beams that are parallel to each other,

and the significant dimension (x) of the object (100) is deduced from the infrared response obtained when the object (100) is moved so as to intercept the first infrared beam and the second infrared beam in sequence, along a direction substantially perpendicular to the direction of the axes (12, 14) of the two beams, said infrared response corresponding to the fraction (24) of the second beam non yet intercepted by the object (100) when it is still intercepting half (22) of the first beam.

5. (original)   System set forth in claim 4, characterised in that the determination apparatus (2) also includes a third photoelectric transceiver assembly (16, 18) arranged on the input side of the first infrared assembly (4, 6) with respect to the second infrared assembly (8, 10) and intended to make a prior adjustment of the intensity of the two infrared beams.

6. (previously amended)   System set forth in claim 4, characterised in that the significant dimension (x) of the object (100) is obtained after moving said object QN times and measuring Q infrared responses RI(q), where q is between 1 and Q, with a relation of the following type:

$$x = A_4.(average \ RI(q))^4 + A_3.(average \ RI(q))^3 + A_2.(averageRI(q))^2 + A_1.(average \ RI(q))^1 + A_0,$$

where A_0, A_1, A_2, A_3, A_4, are coefficients obtained previously applying the same relation to at least four objects with standard dimension (edim), for which an infrared response $RI(_{edim})$ is measured.

7. (previously amended)   System set forth in claim 1, characterised in that the apparatus (30) for determining the attenuated intensity of a photon beam is a gamma spectrometry determination apparatus, comprising:

- an assembly (32) formed from a source and a collimator,

- an assembly (40) formed from a detector and a collimator,

- a gamma photon acquisition and counting system (48).

8. (original)   System set forth in claim 7, characterised in that the acquisition and counting system (48) comprises:

- a high-density germanium detector,

- a preamplifier (50),

- a Digital Signal Processor (DSP) (52),

- a high voltage module (54),

- a network module (56),

- a data acquisition computer (170),

- a cryostat (60).

9. (previously amended)   System set forth in claim 1, characterised in that the transport means (70, 72, 80, 82, 84, 86, 88) comprise a turntable (70) and a stepping motor (72) driving said turntable (70).

10. (previously amended)   System set forth in claim 1, characterised in that the transport means comprise a handling arm (80).

11. (original) System set forth in claim 10, characterised in that the handling arm (80) is an articulated arm equipped with an end clamp (82) intended to grip and put the object (100) down.

12. (previously amended)   System set forth in claim 1, characterised in that the first adjustment means comprise:

- a slide (74) to fix the position of a base (26) of the apparatus (2) for determining

the significant dimension of the object along a direction X;

- an actuator (76) to bring the first infrared assembly (4, 6) closer to or further from the second infrared assembly (8, 10) of said apparatus (2) along a Y direction perpendicular to the X direction;

- an actuator (78) to move said base (26) of said apparatus (2) along a direction Z perpendicular to the plane (X, Y).

13. (previously amended) System set forth in claim 1, characterised in that the second adjustment means comprise an irradiation support (90) onto which the object (100) is installed between a source (32) and a detector (40) in the apparatus (30) for determining the attenuated intensity of the photon beam passing through the object (100).

14. (original) System set forth in claim 13, characterised in that the second adjustment means comprise:

- a slide (94) to fix an irradiation support (90) along a direction X,

- an actuator (96) to move said irradiation support (90) between a source (32) and a detector (40) in the apparatus (30) for determining the attenuated intensity of the photon beam passing through the object (100), along a direction X.

- an actuator (98) to move said irradiation support (90) between a source (32) and a detector (40) in the apparatus (300) for determining the attenuated intensity of the photon beam passing through the object (100), along a direction Z perpendicular to the plane (X, Y).

15. (currently amended) Method for automatically determining the density of an object (100) belonging to a set of objects using a system comprising an apparatus (2) to determine a significant dimension (x) of an object (100) and ~~an~~ a gamma spectrometry apparatus (30) to determine the intensity (I) of a photon beam attenuated by passing through said object (100), characterised in that the method includes the following calibration steps:

- a step 1 to calibrate the position of two infrared assemblies (4, 6; 8, 10) in the apparatus (2) to determine the significant dimension of objects (100),

- a step 2 to calibrate the position of an irradiation support (90) of the gamma spectrometry apparatus (30) used to determine the intensity of the photon beam attenuated by passing through objects (100),

- a step 3 to calibrate the measurement of ~~the~~ a source-detector (32, 40) assembly of the gamma spectrometry apparatus (30),

and in that it includes steps to actually determine the significant dimension (x) of objects (100), that are done on each object (100) in said set of objects.

16. (currently amended)   Method set forth in claim 15, characterised in that the calibration step 1 includes operator input of a set of input parameters using an interactive module. These parameters include:

- configuration of components that have a micrometric displacement including two actuators (76, 78),

- configuration of ~~the~~ a turntable (70), in other words the nature of the objects that occupy different locations provided on the turntable,

- the position occupied by each of the standard dimension ~~object~~ objects (edim) on the turntable (70),

- a position ($Z_{measure}$) along the Z direction of a base (26) of the apparatus (2),

- positions Y(1) and Y(N) limiting a displacement interval of the first infrared assembly (4, 6) along the Y direction,

- a displacement step (INT) of the first infrared assembly (4, 6) along the Y direction.

17. (currently amended)   Method set forth in claim 16, characterised in that the calibration step 1 also includes the following operations:

a) displacement of the base (26) along the Z direction as far as the ($Z_{measure}$) position,

b) angular displacement of the turntable (70) so as to transport [a] one of the standard dimension object objects (edim) as far as its initial measurement position with respect to the apparatus (2),

c) displacement of the first infrared assembly (4, 6) along the Y direction as far as its start position (Y(1)),

d) progressive displacement of the first infrared assembly (4, 6) along the Y direction in successive increments of (INT), moving it away from the second infrared assembly (8, 10) fixed at a position Y_{FIX} between the Y(1) and Y(N) positions, and simultaneous determination of the infrared response (RI(n)) of the object one of the standard dimension objects (edim) corresponding to each position (Y(n)):

e) calculate the optimum infrared response $RI_{OPT,}$

f) calculate the optimum position Y_{OPT} of the first infrared assembly (4, 6) with respect to the second infrared assembly (8, 10).

18. (currently amended)   Method set forth in claim 17, characterised in that the operation d) for progressive displacement includes the following sub-operations:

d-1) angular displacement of the turntable (70) so as to transport ~~the standard dimension object~~ said one of the standard dimension objects (edim) to its final measurement position,

d-2) measure the infrared response (RI(n)) of said ~~the standard dimension object~~ said one of the standard dimension objects (edim),

d-3) angular displacement of the turntable (70) so as to bring ~~the standard dimension object~~ said one of the standard dimension objects (edim) to its initial measurement position.

19. (previously amended)   Method set forth in claim 17, characterised in that the optimum infrared response RI_{OPT} is obtained using the relation:

$$RI_{OPT} = \frac{RI_{MAX} - RI_{MIN}}{2}$$

where: RI_{MIN} is the value of the minimum saturation of the infrared response,

and: RI_{MAX} is the value of the maximum saturation of the infrared response.

20. (previously amended)   Method set forth in claim 17, characterised in that the operation f) to calculate the optimum position Y_{OPT} is obtained as follows:

If $\dfrac{RI_{OPT} - RI(j)}{RI_{OPT} - RI(k)} < 1$, then $Y_{OPT} = Y(j)$

If $\dfrac{RI_{OPT} - RI(j)}{RI_{OPT} - RI(k)} > 1$, then $Y_{OPT} = Y(k)$

where RI(j) and RI(k) are two previously calculated values of the infrared response between which the required optimum response RI_{OPT} lies, that correspond to two positions Y(j) and Y(k) of the first infrared assembly (4, 6) respectively.

21. (currently amended)   Method set forth in claim 19, characterised in that the calibration step 2 includes operator input of a set of input parameters using an interactive module. These parameters include:

- configuration of components that have a micrometric displacement, including two actuators (96, 98),

- configuration of the turntable (70), in other words the nature of the objects that occupy different locations provided on the turntable,

- the position occupied by ~~each standard density object~~ each of the standard density objects (emas) on the turntable (70),

- a measurement duration or count time,

- positions Z(1) and Z(N) limiting a displacement interval of an irradiation support (90) along the Z direction,

- a number M of measurements of the photon intensity attenuated by passing through each ~~standard density object~~ of the standard density objects, for each position Z(i) occupied by the irradiation support, for i=1,...,N.

22. (currently amended)   Method set forth in claim 21, characterised in that the calibration step 2 also includes the following operations:

a) determination of the significant dimension (x_{emas}) of ~~each standard density object~~ each of the standard density objects (emas),

b) angular displacement of the turntable (70) by an angle (A), in order to transport said standard density ~~object~~ objects (emas) into an intermediate position in which ~~it~~ they will be gripped by a gripping arm (80),

c) positioning of said object (emas) on an irradiation support (90),

d) actual adjustment of the position of the irradiation support (90) with respect to a source (32) and an associated detector (40),

e) return transport of the ~~object with standard density object~~ standard density objects with standard density (emas) on the turntable (70) repeating the sequence described in operation c) but in the reverse order.

23. (currently amended)   Method set forth in claim 22, characterised in that operation c) to position the ~~object~~ standard density objects (emas) on the irradiation support (90) includes the following sub-operations:

c-1) displacement of the irradiation support (90) downwards, along the Z direction,

c-2) displacement of the gripping arm (80) from its waiting position to become vertically in line with the intermediate position of the ~~object~~ standard density objects (emas),

c-3) gripping the object emas by the gripping arm (80), and then transport of the ~~object until it is~~ standard density objects until they are vertically in line with the top face (92) of the irradiation support (90),

c-4) displacement of the irradiation support ~~90~~ (90) as far as the position ~~Z(1)~~ (Zi) upwards and along the Z direction,

c-5) put the ~~object~~ standard density objects (emas) down on the top face (92) of the irradiation support (90) using the handling arm ~~80~~ (80),

c-6) displacement and return of the handling arm (80) as far as its waiting position,

c-7) force the ~~object~~ <u>standard density objects</u> (emas) into contact with a stop on the top face (92) along the Y direction.

24. (currently amended)   Method set forth in claim 22, characterised in that the operation d) to actually adjust the position of the irradiation support (90) with respect to the source (32) and the associated detector (40) includes the following sub-operations:

d-1) progressive displacement of the irradiation support (90) along the Z direction between two predetermined positions Z(1) and Z(N),

d-2) for ~~each position   Z(i), i = 1, ..., N~~ <u>the positions Z(i)</u>, irradiation of the standard density object (emas) by the photon beam a number M of times, which leads to a set of values of attenuated intensity I(i, J), where i = 1, ..., N represents the number of successive positions Z(i) occupied by the irradiation support (90) and j = 1, ..., M represents the number of irradiations made at each position Z(i),

d-3) calculate the optimum position (Z_{OPT}) of the irradiation support (90) starting from an order 4 polynomial regression of positions Z(i) with respect to the attenuated intensities I(i, j), this order 4 polynomial regression being predetermined and integrated as a data item of an acquisition, processing and analysis apparatus (200).

25. (currently amended)   Method set forth in <u>claim 19,</u> characterised in that the step 3 to calibrate the measurement of the gamma spectrometry determination apparatus ~~30~~ <u>(30)</u> includes the following automated operations:

a) measurement of the photon intensity (I_{emas}) attenuated by passing through a standard density object (emas),

b) calculate the attenuation mass coefficient (μ_m) of the standard density object, using the following relation:

$$\rho_{emas} = \frac{1}{\mu_m x emas} . L_n \frac{I_{emas}}{I_O}$$

26. (previously amended) Method set forth in claim 19, characterised in that the actual determination steps also include:

- a step 4 to determine the significant dimension (x) of the object (100) to be tested,

- a step 5 to transport the object (100) towards the irradiation support (90),

- a step 6 to adjust the position of the object (100) by adjusting the position of the irradiation support (90) with respect to a source (32) and an associated detector (40),

- a step 7 to determine the attenuated intensity (I) of the photon beam transmitted through the object (100),

- a step 8 for acquisition, processing and analysis of the spectrum obtained,

- a step 9 to determine the relative variation $\frac{\Delta\rho}{\rho}$ of the density (ρ) of the object (100), relative to the density of one or several standard density object(s) (emas),

- a step 10 for return transport of the object (100) as far as its location on the turntable (70).

27. (original) Method set forth in claim 26, characterised in that the step 4 to determine the significant dimension (x) of the object (100) to be tested consists of the operator inputting a set of input parameters using an interactive module. These

parameters include:

- configuration of the turntable (70), in other words the nature of objects that occupy the different locations on the turntable,

- the location occupied by the object (100) on the turntable (70),

- a position ($Z_{measure}$) along the Z direction of the base (26) of the apparatus (2),

- a number P of infrared measurements for each standard dimension object (edim(n)), n = 1, ..., N, where N is the number of standard dimension objects,

- a number Q of infrared measurements for the object (100).

28. (currently amended)   Method set forth in claim 27, characterised in that the step 4 to determine the significant dimension (x) of the object (100) to be tested also includes the following operations:

a) displacement of [a] the base (26) in the apparatus (2) along the Z direction as far as the position ($Z_{measure}$),

b) displacement of a first infrared assembly (4, 6) along the Y direction, as far as a position ($Y_{measure}$) defined by: $Y_{measure} = Y_{OPT} + (X_{edim} - X_{edimAVE})$, where:

Y_{OPT} is the optimum position obtained in calibration step 1,

X_{edim} is the dimension of the standard dimension object (edim) used during the calibration step 1,

$X_{edimAVE}$ is the significant average dimension of all standard dimension objects (edim),

c) measurement of the infrared response RI(p), repeated P times, p = 1, ..., P of N standard dimension objects (edim(n)), n = 1, ..., N, which leads to a set of values RI(n, p),

d) actual calculation of the significant dimension of the object (100).

29. (currently amended)　Method set forth in claim 28, characterised in that the operation d) to actually calculate the significant dimension (x) of the object (100) is done as follows:

d-1) use of an order 4 polynomial regression of the significant dimensions $x_{edim}(n)$ of each of the ~~N objects with standard dimension~~ standard dimension objects (edim), as a function of the average $RI_{edimAVE} = \dfrac{\sum RI(n,p)}{P}$ of infrared responses of said ~~object with standard dimension edim(n)~~ standard dimension objects (edim) to calculate the coefficients A_0, A_1, A_2, A_3, A_4 of a relation of the following type:

$$x_{edim}(n) = A_4 \cdot (RI_{edimAVE}(N))^4 + A_3 \cdot (RI_{edimAVE}(n))^3 + A_2 \cdot (RI_{edimAVE}(n))^2 +$$

$$A_1 \cdot (RI_{edimAVE}(n))^1 + A_0,$$

d-2) measurement of the infrared response $RI(q)$, repeated Q times, $q = 1, \ldots, Q$ of the object 100 to be tested, and calculate the average $RI = \dfrac{\sum RI(q)}{Q}$ of these infrared responses, and calculate the significant dimension (x) of the object (100) by the following relation:

$$x = A_4 \cdot (RI)^4 + A_3 \cdot (RI)^3 + A_2 \cdot (RI)^2 + A_1 \cdot (RI)^1 + A_0$$

30. (previously amended) A method according to claim 15 wherein the objects are nuclear fuel pellets.

31. (previously amended) A method according to claim 30 wherein the method is applied during manufacture of the nuclear fuel pellets.